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YELLOWJACKET ABATEMENT IN CALIFORNIA PARKLANDS

STATE OF CALIFORNIA
Department of Food and Agriculture
Division of Pest Management, Environmental Protection and Worker Safety
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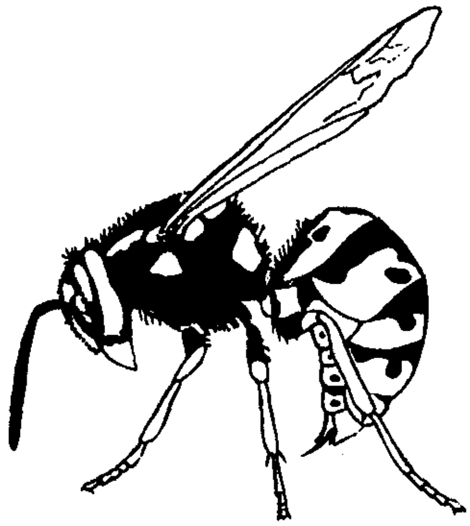
YELLOWJACKET ABATEMENT IN CALIFORNIA PARKLANDS



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STATE OF CALIFORNIA
Department of Food and Agriculture
Environmental Monitoring and Pest Management

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YELLOWJACKET ABATEMENT IN CALIFORNIA PARKLANDS

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INTRODUCTION

Pestiferous yellowjacket species are those which are general scavengers at sites linked with human activity, The most important yellowjacket problem in many situations is not the stinging, but the considerable annoyance and alarm created by the presence of large numbers of scavenging yellowjackets and the threat of being stung. Large yellowjacket populations cause dramatic drops in park, campground, and resort attendance (Akre et al., 1980).

Unnatural food sources in parklands, such as garbage cans, discarded food materials, and trash and garbage dumpsites, offer much greater sustenance to scavenging yellowjacket species than they can find in nature. Their numbers may increase far beyond those found in natural environments where population size is limited by the availability of insect prey and proteinaceous foods (Ennik, 1984). The relative importance of yellowjackets in relation to other venomous arthropods will probably increase with the growth of human population, and particularly with the increase in the number of parks, recreation areas, and suburban developments in formerly uninhabited places (Ebeling, 1978).

Yellowjackets have important ecological roles as natural biological control agents of pestiferous insects and are important scavengers of both invertebrate and vertebrate carrion. The adults of most species feed primarily on meat, sweet liquids, or ripe fruit, but they also destroy large numbers of insect pests, which they feed to their young (Bell and Wagner, 1981). Their beneficial role as scavengers is probably just as important in urban and suburban areas as it is in rural areas or in the forest (Akre, 1982; Roush and Akre, 1978a).

Yellowjackets are primarily north temperate species occurring in Asia, Europe, northern Africa, and North America. Over the northern areas of their range they are undoubtedly the dominant social wasps in numbers of colonies and individuals (Akre, 1982).

CLASSIFICATION

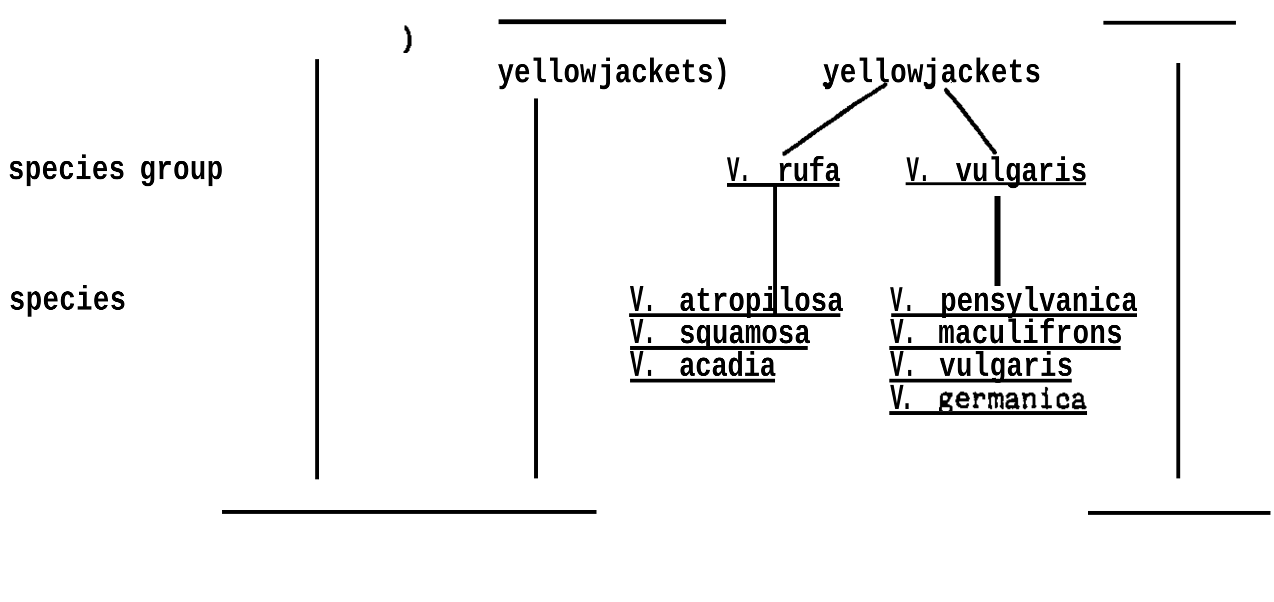
Some fifteen or more species of vespine wasps occur in the United States, at least eleven of which are found in California. Most of these are similar, but easily distinguished when the details of their structure and coloring are examined.

The family Vespidae (order Hymenoptera) is divided into seven subfamilies; the Vespinae, Polistinae, and Polybiinae are social wasps, while the remaining subfamilies consist of solitary wasps. The subfamily Vespinae (vespine wasps) contains the typical yellowjackets, so called because of the black and yellow pattern of the majority of species. Most yellowjackets are cross-banded black and yellow on the abdomen and the head and thorax are black with yellow spots and bars. A few species have the yellow replaced by white and a few have the black partially or completely replaced by reddish or rust color.

The term yellowjacket applies to any member of the ground or aerial-nesting wasps belonging to the genera Vespula and Dolichovespula (Akre et al., 1980). The subterranean nesting yellowjackets belong to the genus Vespula and the aerial-nesting species to the genus Dolichovespula. The Vespula consist of two species groups, the V. vulgaris (L.) group and the V. rufa (L.) group. The species of the V. vulgaris group are the most pestiferous in California. The species not listed below in Figure 1 are rarely encountered in California.

Figure 1. Classification of commonly encountered species in California

Order Hymenoptera



Courtesy of USDA Forest Service

The facial morphology provides the taxonomic character that distinguishes the Vespula and Dolichovespula genera (Ebeling, 1978). Dolichovespula are distinctly long-faced ("dolicho" means long). They show a distinct space on the side of the head between the lower end of the compound eye and the base of the mandible, whereas the species of Vespula are short-faced and lack this space. The species of Dolichovespula also exhibit a very fine ridge running up and down on the sides of the prothorax, and they have long hairs on the tibiae of the legs, whereas the species of Vespula lack these features (Duncan, *1933).*

All vespine wasps have a broad abdomen that is abruptly truncated at the base. In the queens and workers, the stinger is concealed in the base of the abdomen, which tapers to a sharp point apically. The eyes are large, covering most of the sides of the head. They are kidney-shaped and bear deep, rounded indentations on their front margins. The wings, when the wasp is not in flight, are folded lengthwise down the middle and are held flat along the back.

Certain of the larger vespine wasps are called hornets. It is not uncommon to hear some confusion regarding appropriate use of the terms wasp, hornet, and yellowjacket. One way of approaching this is to remember that all hornets and yellowjackets are wasps, but only a few of the wasps are hornets and yellowjackets. In the United States, the term hornet is generally applied to Dolichovespula maculata (baldfaced hornet) and Vespa crabro (European hornet), and sometimes to all aerial-nesting yellowjackets. Technically, however, only species in the genus **Vespa** (of which V. crabro is the only North American example) are hornets (Akre et al., 1980).

The Polistes, or paper wasps, are long slender wasps that seldom bother man unless they are defending their nests. Their colonies consist of less than *100* wasps, and their open-faced paper nests hang downward and are not enclosed in envelopes like those of vespine wasps (Putnam, **1977).** They eat nectar and liquid food and help control other insect populations by feeding them to their larvae. Paper wasps are most often found in close association with man.

COMMON SPECIES

The most pestiferous species of vespine wasps in California are V. pensylvanica, V. vulgaris, and V. germanica. The other species discussed below are those which may also be encountered, although they may be only infrequently observed and may not be pestiferous. Refer to Figure **3** for an illustration of each species discussed below.

Vespula pensylvanica (Saussure), western yellowjacket
This ground nesting species is the most common and most pestiferous yellowjacket in California and in the western United States. The queens are about 20 mm long. The workers are about *16* **mm** long, and the typical pattern of their black-and-yellow markings distinguishes them from other species (Ebeling, *1978).*

The western yellowjacket occurs throughout the western United States and adjacent Canadian provinces in dry grass and oak woodland habitats (Ebeling, 1978; Ennik, 1989). Nests of this species are common in foothill residential developments, parks, campgrounds, and other inhabited areas. Nests are usually subterranean and most are constructed in rodent burrows (Bohart and Bechtel, 1957; Duncan, 1939; MacDonald et al., 1974; and Smith, 1956).

This species is both a predator and a scavenger in obtaining proteinaceous food for the larvae. A variety of prey is accepted, including slugs, harvestmen, spiders, grasshoppers, flies, spittlebugs, froghoppers, and bugs. The preponderance of prey are Hemiptera and Homoptera (Akre, et al., 1976; MacDonald et al., 1974). Workers scavenge for bits of meat from any source (Ebeling 1978; Akre et al., 1980). Characteristic of all social wasps, the workers change their feeding habits from protein to carbohydrate (eg. nectar) especially in the latter part of the season when there are no more larvae in the nest (Ebeling, 1978).

Although there are great variations in the size of populations from year to year, yellowjackets are responsible for many human stinging incidents each year (Wagner and Reierson, 1969). Periodic population outbreaks associated with warm, dry weather of spring occur every 3 to 5 years or slightly longer. Colonies commonly nest in yards or recreation areas, where the chance of colony disturbance and resulting stings is great (Akre et al., 1980).

This species responds both to meat baits and heptyl butyrate lures (commercially available). Foragers are present from June to November (Ennik, 1989).

Vespula _vulgaris_ (L.), common yellowjacket
This is a common species and is second only to _V._ _pensylvanica_ as a pest in the western United States. It is similar to _V. pensylvanica_ in appearance. It occurs in all the western states, throughout the northern states of the East and the adjoining areas of Canada, throughout western Canada, and in Alaska. In California, it is usually found north of Fresno (Ebeling, 1978), where it occurs in wooded areas; it is a major pest in the oak-madrone woodland habitat of the northern coastal area. It makes its nests in cavities in the ground, in hollow trees and logs, and in wall voids of buildings (Ennik, 1989). Colonies are large, with 1000 to 3000 workers, often persisting into late autumn (Mallis, 1982).

This species responds to meat baits but _not_ to heptyl butyrate. Foragers are present from June to November (Ennik, 1989).

Vespula _germanica_ (F.), German yellowjacket
This species, a common pest yellowjacket in Europe and England, has been introduced many times into the northeastern United States since 1900. It may be confused with _V._ _vulgaris_ in both habit and appearance. In about 1975, _V._ _germanica_ began to spread across the northern half of the United States, mainly due to transport of hibernating, fertile queens in both recreational and commercial vehicles. It is anticipated that this species will continue to expand its range into nearly all of western North America, and will become the dominant, scavenging yellowjacket in many areas (Akre et al., 1989). It is expected to become established in the cooler areas of the coast and sierra ranges in ground nests and in wall voids and attics of structures.

It has become a serious pest, especially in urban areas, across North America because of its propensity to nest in man-made structures (MacDonald et al., 1980; Akre et al., 1989). The presence of this species is always perceived as a serious health threat. It has become the dominant species in some of the localities it has invaded (Akre et al., 1989). The workers are very aggressive scavengers; they prey on a wide variety of arthropods and are opportunistic in the exploitation of other food sources, Most workers forage within several hundred meters of the nest, but some will travel up to 1,200 meters. They are also notorious scavengers for protein and are attracted in great numbers to sweets (Akre et al., 1980). Colonies (and nests) are frequently large and usually persist late into the fall, They may continue into a second year in warmer climates.

This species responds well to meat baits but not to chemical lures. Foragers are present from June to November (Ennik, 1989).

<u>Vespula</u> <u>atropilosa</u> (Sladen), prairie yellowjacket
This species is not usually a pest. The prairie yellowjacket occurs throughout the western states (Ebeling, 1978). Specimens have been collected from ground nests along the Sacramento River (Ennik, 1989). It is abundant in rangeland and open forest areas, but becomes increasingly less abundant in heavy forest. It also commonly nests in yards, pastures, golf courses, and similar areas. Workers are predators only on live prey. They often attack spiders, harvestmen, flies, caterpillars, hemipterans, and some homopterans, but seldom attack other Hymenoptera or beetles. Colonies are often found in yards, however, workers are usually no problem unless the colony is disturbed (Akre et al., 1980).

It responds to both heptyl butyrate and meat baits. Foragers are present from June to November (Ennik, 1989).

<u>Vespula</u> <u>sulphurea</u> (Saussure), California yellowjacket
This species is easily recognized by the two longitudinal yellow bars on the thorax. It is widespread in California but is most common in the northeastern area. It has also been found in southern Oregon, western Nevada, southeast Arizona, and in northern Baja California (Ebeling, 1978). The California yellowjacket is often observed taking water at the stream edge along wooded creeks, Members of this species are not very abundant, nor are they considered pestiferous to man. Food items consist entirely of spiders and insects (Ennik, 1989).

This species does not respond to either meat baits or heptyl butyrate lures. Foragers are present from June to November (Ennik, 1989).

<u>Dolichovespula arenaria</u> (P.), aerial yellowjacket
This aerial nesting species is one of the most common vespine wasps in North America. It occurs throughout the western and northeastern states, and in most of Canada and Alaska. It is not found in the Plains states, and is absent in all but the northernmost areas of the southern states (Ebeling, 1978). The aerial yellowjacket is prevalent in northern California in wooded and suburban areas. It constructs a football-shaped paper nest usually in shrubs or trees, but often under the eaves of

buildings (Ennik, 1989; Mallis, 1982). This species is not frequently observed and is usually not a pest, except when nests are constructed near walkways or building entrances, It is not a meat scavenger; food items consist entirely of spiders and insects (Ennik, 1989).

This species does not respond to either meat baits or heptyl butyrate lures. As populations of other yellowjacket species within the range of V. arenaria increase during summer, this species declines (Ennik, 1989). Foragers are present from May to September (Ennik, 1989).

Dolichovespula maculata (L.), baldfaced hornet
This species is morphologically more similar to the yellowjackets than to the hornets. However, it resembles the hornets in behavior as well as size. It is cream and black in color, Its white markings make the term yellowjacket inappropriate. The worker caste cannot be separated from the queen caste on the basis of external morphology. There is a broad range of sizes in the females; they are sometimes as large as the queen (Ebeling, 1978).

The species occurs throughout the United States, but is scarce in the southern half of the country. It is abundant in the northern half of the United States and the southern portions of the adjacent Canadian provinces from the Pacific to the Atlantic. Its range extends into the Yukon Territory and also into Alaska (Ebeling, 1978).

In California, this species occurs primarily in the north coast mountain ranges and at moderate elevations in the Sierra Nevada. It is not found in Southern California (Ebeling, 1978). It occurs in wooded and forested areas and is a summertime pest in recreational as well as suburban areas (Ennik 1989). This species also constructs a football-shaped paper nest attached to trees and on buildings. The nests may become very large by the end of the summer (Mallis, 1982).

This species responds to meat baits but not to heptyl butyrate lures. Foragers are present from June to October (Ennik, 1989).

BIOLOGY

INTRODUCTION
In addition to accurately identifying the yellowjacket species, it is necessary to become very familiar with the biology of the species and its interaction with human activities in the area, in order to develop an effective abatement strategy. The consideration of yellowjackets as pests is directly related to their behavior and feeding habits; they are pestiferous when gathering food for large community nests and when displaying protective behavior (Putnam, 1977). The following discussion of biology is applicable to all species of yellowjackets. The different species exhibit the same general behavior, although the habits of individual species vary.

Yellowjackets depend primarily on sight and smell for gathering food and communicating. They cannot hear airborne sounds, but can sense sound vibrations through their feet. They react strongly to tapping, rasping, and scraping sounds like those from lawnmowers or chainsaws. They are extremely sensitive to odors and their antennae can locate sources from great distances (Putnam, 1977).

Members of Vespula and Dolichovespula differ not only in the location of their nests but also in the details of nest construction, In the duration of life of the colony, in the time of year when males and queens are produced, and in the physical structure of their bodies (Duncan, 1933).

The V. vulgaris species group has been well studied in Europe and North America, probably as a result of the large colonies and pestiferous workers produced by members of this group. They are notorious scavengers, especially pestiferous in recreation areas and outdoor picnic areas (Figures 1,3, and 4).

Workers of the V. rufa species group are not pests of man. Their colonies are small. They complete their life cycle by early September, feed strictly on insects, and do not scavenge for human food (MacDonald et al., 1976).

Dolichovespula are not attracted to protein baits and usually forage only for live prey, but occasionally will scavenge flesh from animal carcasses (Green et al., 1976). In this respect, their behavior seems intermediate between the Vespula rufa group species (strictly live prey foragers) and the Vespula vulgaris group (frequent scavengers)(Akre et al., 1980).

SEASONAL HISTORY

The colony begins its decline in the fall (Figure 5). Workers begin building the reproductive cells (larger than other cells) in which the reproductive wasps are born and raised. When new queens and males emerge, they leave the nest and mate. The males die soon after mating and the females seek appropriate overwintering sites. At this point, the queen that initiated the colony dies and the worker wasps disperse, dying with the onset of cold weather.

The impregnated females are the only survivors of the previous year's colony. They survive the winter in hibernation and serve as next year's queens. Each hibernates singly at a hidden location such as within a wall void in a building, beneath loose bark on a dead tree, or in a pile of lumber. After emerging from hibernation in the spring, the queen constructs a small nest (Figure 8) of up to 45 cells. The queen lays her eggs in these cells and forages for nectar and arthropod prey to feed the developing larvae. The first four to seven workers (all workers are female) emerge in about 30 days and assume all the duties of the colony. After a short period of additional foraging, the queen no longer leaves the nest and her only responsibility is egg-laying. Until this time, colony growth is slow but becomes exponential by midsummer as successive broods of workers are reared (Akre et al., 1980).

CASTES

The vespine wasps (except for two parasitic species) consist of three types, or castes, of individuals: the queen, the worker, and the male or drone. The queen and worker are both female and differ principally in size. The queen is much larger than the worker due to her fully developed reproductive organs. There are also slight differences in color pattern. Both queens and workers sting; the stinger is a modification of the egg-laying structure of females. The males are longer-bodied, more slender, and have longer antennae than females. Males have one more segment in the antennae and one more obvious segment in the abdomen than females. The tip of the male abdomen is blunt or rounded rather than pointed; they have no sting and they differ slightly in color pattern. Males are present in a colony or on the wing only in summer and fall, mostly in the fall, and are rarely seen by the average person.

Workers

The workers perform all the tasks required for the maintenance of the colony: nest-building, foraging for food, caring for the brood and for the queen, and defending the colony. If the queen is killed when a nest is destroyed, many of the workers will take up the duty of egg-laying. The same thing occurs in an undisturbed nest if the queen dies. The workers, not having been mated, lay only unfertilized eggs. These eggs hatch (as do unfertilized eggs laid by a queen) and give rise to male wasps only. Egg-laying workers do not show the same adaptation to the problems involved with egg-laying that queens do. A queen never lays more than one egg in a cell, but workers may lay six or eight, though only one larva can possibly be reared from the lot. The presence of many such eggs in a wasp nest is an indication that the colony is queenless.

Queens

In the early spring when a wasp colony is beginning, the queen performs both her egg-laying duties and all those duties usually performed by workers. In the earliest stage of a oolony, the queen is the only inhabitant of the nest. After her first brood matures, the queen gives up all the duties except egg-laying. The queen lives but one season, during which she may lay 20,000 eggs.

Drones

The male yellowjacket, or drone, has but one function, which is to mate with and fertilize a newly-hatched queen. Except in orphaned colonies in which there are egg-laying workers, males are produced only toward the close of a season. This is true also of the queens. The males mate with young queens from their own or from other nests, no discrimination apparently being made. A male will often mate with several queens. Males spend their time feeding on nectar from summer and fall flowers after leaving the nest. After a few days or weeks of feeding, the males die.

NEST

All vespine wasps, whether aerial or subterranean in nesting habit, build large nests of paper, which they make of wood pulp (Figures 6 and 9). Each nest consists of a series of paper combs, usually 5-8 in number, which resemble the wax combs of the honeybee in that the cells are hexagonal in shape. They differ from the combs of the honeybee in several respects. Each wasp comb consists of but one layer of cells instead of two back-to-back layers as in the bee comb, and the combs are placed horizontally with the open ends of the cells facing downward, whereas the bee combs are placed vertically with the cells opening outward on each side. The combs of wasps nests are used only for rearing of the brood, whereas the bee uses part of the combs for the storage of food in the form of honey.

The making of paper and the incorporation of this into the structure of the nest is one of the principal duties of worker wasps. The wasp leaves the nest, looking for weathered wood of some sort from which she may scrape or cut wood fiber. It matters little what the object is as long as it can supply the needed wood pulp. As soon as enough fiber is collected, the wasp carries it back to the nest and chews it into a doughy mass of paper pulp and applies it to the older paper. The moisture evaporates from the new paper and it becomes an integral part of the nest.

To enlarge their nest, yellowjackets remove the inner layers of the envelope and add to the sides of the combs, build additional combs below, and put new layers on the outside of the envelope (Comstock, *1960).* The nest is constantly being expanded to meet the needs of the colony. Part of the paper torn from the inner layers of the nest wall is used to enlarge the combs.

Species which nest underground have more work to do when building nests than do the aerial nesting species. The underground species must not only make paper and enlarge the nest, but they must also excavate the chamber in the ground in which the nest is built (Figure **7).** This is a considerable task, as the nests are often built in dry, hard ground. Nests may be over *30* centimeters in diameter. The excavation proceeds at a rate that depends on the speed with which the colony itself is developing. Species that generally build their nests underground may not always do so if adequately protected nest sites can be found above ground.

Workers promptly attempt to repair a damaged or partially destroyed nest. If the damage is too extensive, the uninjured workers will build a new nest at the same site of a nest which was destroyed (flies, ants, and molds will rapidly add to the damage of a nest which has sustained immediate damage from a physical blow).

The workers keep the nest clean and renovate vacated cells so they may be used again for brood-rearing. The immediate re-use of vacated cells, together with the manner in which wasp nests are continually enlarged during the life of the colony, results in concentric zones of broods of different ages in each comb.

FOODS AND FEEDING BEHAVIOR

Foraging workers collect the **food** supply for the wasp colony. If differences in larval and adult habits are disregarded, wasps may be described as practically omnivorous, as the foodstuffs they consume are numerous in kinds and diverse in character. Most of the **food** eaten by wasps can be divided into two categories--liquid foods high in sugar content, and animal matter. The liquid foods, the most important source being the nectar of flowers, are primarily energy-yielding foods and are eaten by adult wasps. The animal matter, such as the fleshy tissue of spiders and immature insects or the flesh of dead animals, is primarily tissue-building food and, except for the juices which may be sucked from it by adults, is eaten entirely by larval wasps (Duncan, 1939). Wasps kill their soft-bodied insect or spider prey by biting it, not stinging. It is taken back to the nest, chewed into a pulp and given to the larvae. Because of their consumption of other pest insects, especially plant defoliators, all yellowjackets are beneficial to man.

Meats and carbohydrates left over from human activity, such as in picnic and garbage areas, are very attractive forage. Scavenging yellowjackets are especially pestiferous during August and September when the protein seeking workers aggressively compete with man for food (Akre et al., 1975; Putnam, 1977).

Yellowjackets hunt independently and are unable to communicate food sources to other members of the colony. (Kalmus, 1954; Kemper, 1962). Foraging for arthropod prey is largely by sight. However, individuals scavenging for protein respond to odors, especially at close range (although visual cues undoubtedly play a part).

Although foraging behavior of several species of yellowjackets has been investigated extensively with regard to light, temperature, weather and other factors (Spradbery, 1973), foraging distances of most yellowjackets have not been determined (Akre et al., 1975). However, the data from studies by Akre et al.(1975) and Arnold (1966) suggest that most yellowjackets do not forage far from their nest. Arnold (1966) determined that workers of V. *rufa* and Dolichovespula sylvestris (Scopoli) foraged within 200-300 yards of the nest, although one worker of V. *rufa* was recovered 1000 yards from its nest.

FEEDING THE LARVAE

When feeding the larvae, a worker walks about over the surface of a comb carrying a pellet of insect paste made by malaxating (chewing and squeezing) arthropod prey. The workers feed on juices while malaxating the prey in the nest. When the prey is softened and reduced in size, the worker bites off little bits, giving a bit to each of several larvae until the pellet is gone. As workers feed larvae, they obtain a sweet salivary secretion from the larvae. This reciprocal feeding of the adults by the larvae is praoticed by all the social insects (except the bees) and appears to be one of the strongest bonds holding the members of a colony of social insects together.

COLONY DEFENSE

Worker wasps manifest a strong attachment for the colony and they cooperate promptly and effectively to defend it. They sting only on provocation, though the provocation may be unintentional. A thriving colony of yellowjackets may be watched in comparative safety at close range, provided the watcher is not too conspicuous. To stand in front of an aerial nest or lean over an underground one, however, may appear threatening to the yellowjackets and may lead to trouble. Also, standing in traffic lanes used by wasps coming to and from a nest may lead to a collision with a flying wasp. Such a collision may be interpreted as a provocation. Wasps which get into automobiles often sting. They become excited by the collision with the automobile or when someone leans or sits on them.

OUTBREAK YEARS

In most of the country, wasps vary greatly in abundance from year to year. Possible causes underlying the conspicuous changes in annual abundance of yellowjackets, Vespula spp., have been discussed in the entomological literature for nearly 100 years (Roush and Akre, 1978a). Reviews of the topic include Spradberry (1973), Archer (1980), Akre and Reed (1981b), and Roth and Lord (1987). Most of the literature has been directed toward: identifying the causes for conspicuous years of extreme population abundance and scarcity; the apparent lack of periodicity in these population levels; and the influence of weather as a primary factor affecting yellowjacket abundance. (Weather data were used to predict the population outbreaks of 1973, 1977, and 1979 in the Pacific Northwest) (Akre and Reed, 1981b).

Wasp outbreaks are believed to result, at least in part, from a relatively mild winter and early spring (Bohart, 1941). The number found in late summer depends to some extent on the weather during the preceding spring. If an early spring prompts queens to establish their nests and the weather then becomes inclement for a prolonged period, the wasp population can be greatly diminished (Andrews, 1969).

Regional fluctuations in wasp populations are more likely to occur in the mountains than in the lowlands, for the insects are more adversely affected by severe spring weather. In California, the wasp population is far less variable from year to year than it is in parts of the country with more severe changes in spring weather (Akre et al., 1980; Ebeling, 1978). Although this is generally true, there can also be dramatic differences from year to year in California. An example is demonstrated by the difference in the number of nests treated at Lake Tahoe during 1989 (462 nests) and during 1990 (56 nests) (Bissell, 1990).

The only outbreak populations of yellowjackets that have occurred in the Pacific Northwest since 1971 have been when the period from April through June was warm and dry (Akre and Reed, 1981b). Weather seems to affect colonies of V. pensylvanica and P. vulgaris equally at the 'critical stage' (see discussion below), but once this period is passed, colonies of V. pensylvanica are relatively unaffected by weather, especially from August onward. Conversely, colonies of V. vulgaris are probably susceptible to weather conditions throughout the colony cycle, and very abundant populations of this species occur only in drought years. In fact, outbreak populations of this species are on record for nearly every year of drought in the Pacific Northwest (Akre and Reed, 1981b).

Records show that years of relative scarcity of yellowjacket numbers had temperatures below normal and precipitation higher than normal (Akre and Reed, 1981b).

Density-dependent competition for nests or nest sites has also been proposed as a major factor underlying the patterns in abundance of yellowjackets. Other density-dependent factors such as disease, predators, and parasites are also important (Archer, 1973, 1980; Ennik, 1973a; Matthews, 1982; Spradbery, 1973).

CRITICAL. STAGE

Most researchers of social vespine wasps agree that the greatest mortality of populations occurs among overwintering queens before nest establishment, or more importantly, among colonies during the initial stages of growth up until the emergence of the second brood of adults (see Spradbery, 1973; Edwards, 1980). Studies of yellowjacket biology in the Pacific northwest confirm this, and suggest that sometime during April through June the colony reaches a "critical stage" consisting of the queen and the first four to seven workers. Factors affecting the colony at this stage greatly influence its survival, its ultimate size and vigor, or both (Akre and Reed, 1981b).

DAMAGE

Throughout the summer and early fall, the enormous increase in the number of yellowjackets and larvae in each nest causes the wasps to become increasingly pestiferous. In the fall as the protein food supply becomes more scarce, the workers become more aggressive and irritable. During this same period, the queen produces eggs which develop into queens and males. Since these newly formed reproductives are the final larvae produced in the nest and are not nearly numerous enough to provide the food requirements of the large number of workers, the workers begin to feed on nectar, fruit juices, and soft drinks in order *to* survive. When this abrupt change in feeding behavior is observed, the normal decline and death of the colony is near.

The pestiferous nature of some species occurs during a limited period of their annual cycle. This period is from late summer until early autumn when scavenging yellowjackets reach their maximum population levels. Their scavenging on human foods can make them a great nuisance at outdoor activities, and stinging poses a serious medical threat (Reid and MacDonald, 1986).

MEDICAL

Wasps can be aggressive and may severely sting anyone disturbing or appearing as a threat to them or their nests. Wicher et al. (1980) stated that Vespula are responsible for most stings. However, many stings are also due to D. arenaria and D. maculata (Akre, 1982). The stinger is similar to that of a honeybee except it is slightly larger and is not barbed. The yellowjacket can pull out its stinger to repeatedly sting its victim. When stinging, the yellowjacket injects a venom into the victim. The venom is a complex mixture of chemicals, the most common of which is histamine. Human reaction varies; the intensity of the reaction is dependent on the number of venom ingredients to which the body reacts. Painful swelling from the sting can last several days and, in some cases, may require a doctor's care. Localized reddening and swelling almost always occurs. A more severe reaction may last for days and be of concern if the wound is on the neck, throat, scalp, or tongue where it may impair vital body functions.

The clinical severity of reaction to insect bites and stings has been classified by Mueller (1959 a,b), based on a study of 84 patients stung by bees or wasps, as follows:

Group 1
- Slight General Reaction
  - Generalized urticaria (inflammation, wheals, itching, malaise, and anxiety)

Group 2
- General Reaction
  - A slight general reaction plus 2 or more of the following:
    - generalized edema (swelling)
    - constriction of the chest
    - wheezing
    - abdominal pain
    - nausea and vomiting
    - dizziness.

Group 3
- Severe General Reaction
  - Any of the above reactions plus 2 or more of the following:
    - dyspnea (difficulty in breathing)
    - dysphagia (difficulty in swallowing)
    - hoarseness or thickened speech
    - confusion
    - feeling of impending disaster.

Group 4
- Shock Reaction
  - Any of the above reactions plus 2 or more of the following:
    - cyanosis (blue color because of insufficient oxygenation of blood)
    - fall in blood pressure
    - collapse
    - incontinence (inability to restrain natural evacuations)
    - unconsciousness.

In Mueller's investigation, there were a few patients in each group who reported a very rapid onset of symptoms after being stung or bitten - as brief a period as 2 minutes. The average reaction time reported declined from 24 minutes for group 1 to only 5 minutes for group 4 (Ebeling, 1978).

Hypersensitive reaction to yellowjacket venom is quite common, and deaths from this cause have been documented (Ennik, 1980; Parrish, 1963). Some allergists believe that about one percent of the general population is hypersensitive to Hymenoptera venom (Settipane et al., 1972; Hunt et al., 1976 as cited in Ennik, 1980). In 1981 it was estimated that one million Americans per year suffer potentially serious reactions to insect stings, of which 50 or more die (Valentine, 1981; Akre et al., 1980). In a study by Ennik (1980), data abstracted from 34 death certificates in California from 1960-1976 indicate that Hymenoptera accounted for 56 percent of the human deaths from venomous animal groups. Sixteen deaths or 84 percent of the recorded fatalities due to Hymenoptera stings occurred in persons 40 years of age or older. People younger than 40 years of age apparently are less susceptible to fatal stings of Hymenoptera because hypersensitivity to the venom has not yet developed. Most deaths caused by Hymenoptera were attributed to a single sting, although two death certificates indicated that the person had died from multiple stings. Apparently, most victims of fatal Hymenoptera stings were unable to obtain medical help in time and died within an hour, in most cases (14 of 19) because of anaphylactic shock.

Anaphylaxis is hypersensitivity, or in other words, severe allergic reaction. Anaphylactic shock refers to the most severe or violent reactions (Putnam, 1977)(see Mueller's group 4 symptoms above). The following is taken from Ebeling (1978) regarding anaphylaxis: "Although 'allergy' was originally meant to include all forms of human hypersensitivity, the term has later been generally applied to a group of diseases Such as hay fever, asthma, urticaria, and eczema, all the consequences of an immune response to an exogenous factor. While allergic conditions develop spontaneously and only in some individuals, presumably from mild exposure to environmental agents, a more intense reaction, called anaphylaxis, requires intense artificial exposure, usually by injection. The allergic response can develop only in some individuals, but anaphylactic response can be obtained in all individuals of a species".

An increasing amount of research is being directed toward investigating components and medical effects of vespine and other insect venoms (Edery et al., 1978; Nakajima, 1986; Schmidt, 1982). Additionally, many severely allergic people are undergoing desensitization.

The following measures are helpful in avoiding stings:
(from Akre et al. 1980).

1. Do not wear perfumes, hair sprays, suntan lotion, and cosmetics, as yellowjackets are attracted to these compounds.
2. Wear light-oolored clothing such as white or tan.
3. Do not walk outside barefoot.
4. Exercise care when gardening, mowing a lawn, and cutting shrubbery.
5. Avoid outdoor cooking and eating during the yellowjacket season. Even more important than the above, people should try to remain calm in the presence of yellowjackets. If wasps are gently brushed off the body when they alight instead of being swatted, chances of being stung are reduced oonsiderably. When yellowjackets are present at picnic tables, the same principle holds: move slowly and deliberately instead of rapidly, and the wasps will rarely sting. When a yellowjacket is discovered in a moving automobile, the car should be driven off the main road quickly and the wasp removed or killed. It usually poses no threat to the driver as long as all movements are careful and unhurried.

It is probably not as well known that yellowjackets can cause terror in animals. In one case in El Cajon Valley, California, 15 horses developed abscesses from V. pensylvanica stings. Yellowjackets subsequently foraged for flesh from the abscessed areas, terrorizing the animals (Hawthorne, 1974).

RECREATIONAL

In addition to the nuisance to outdoor recreation activities and the health threat to hypersensitive persons, scavenging yellowjackets are sometimes responsible for considerable financial losses to both government agencies and private organizations that provide outdoor recreation facilities. Attendance revenues are often drastically reduced during years of yellowjacket outbreaks. These organizations are becoming increasingly concerned about finding better ways to protect their patrons from yellowjackets. Increased emphasis on recreational activities is a contributing factor to an increase in stinging episodes from yellowjackets (Akre et al., 1980).

URBAN

Yellowjackets and similar wasps are often a nuisance around homes, swimming pools, orchards, and other areas that offer water or food. Yellowjackets are a principal concern to homeowners in urban, suburban, and rural areas. The magnitude of the problem is reflected by the large number of calls to Pest Control Operators for help in reducing wasp populations or eliminating colonies which become pestiferous. In these situations, exact identification is important to prevent the undesirable elimination of beneficial wasp species (vespine or other) if they are out of the way or if normal human activities do not seem to provoke colony workers. Education of people living or working near such wasps is important and can be a very interesting educational experience to all exposed to the beneficial activities of these beneficial species.

Vespula germanica is of special concern to homeowners and businesses since nearly all colonies in the United States are located inside structures (MacDonald et al., 1976). These colonies sometimes chew through ceilings or walls in their continuing efforts to expand the nest, releasing workers into the main rooms of houses (Akre, 1982). V. pensylvanica is well known for this type of damage at Lake Tahoe, primarily at the end of the season when cold weather prompts homeowners to turn their heaters on (Bissell, 1990).

AGRICULTURAL

While yellowjackets can be beneficial predators in fruit orchards, they can also be pestiferous by feeding on the fruit and by disrupting harvesting operations by stinging the laborers (Akre et al., 1980). This is especially true in peach orchards, although it also occurs to a lesser extent in pear, apple, and plum orchards. Vespula pensylvanica is primarily responsible for these problems in the Pacific northwest. Some problems, especially during pruning operations, are caused by colonies of Dolichovespula arenaria and D. maculata nesting in the trees (Akre, 1982). Yellowjackets are also a problem in grape vineyards and can be responsible for nearly total devastation of the crop (Akre, 1982).

Hawthorne (1969) reported that yellowjackets in California cost agricultural operations an estimated $200,000 in 1968. Most of these losses were due to attacks of yellowjackets on fruit pickers and feedlot workers. Davis (1978) also estimated that thousands of dollars are lost annually in beekeeping throughout the world because of yellowjackets. Even in North America, yellowjackets are a nuisance to beekeepers, often creating severe financial losses (Akre et al., 1980). In all these instances, yellowjackets are directly responsible for lost man-hours, lost wages, and medical expenses due to treatment of stings, and thus are a factor when assessing the overall economic importance of yellowjackets (Stein and Wrensch, 1988).

A continuing problem for commercial field workers and for homeowners is the feeding by yellowjackets on berries such as strawberries and raspberries. Stings are common, and some people refuse to pick these berries during abundant yellowjacket years (Akre, 1982).

FOREST

Yellowjackets are also a problem for loggers, sawmill operators and Forest Service personnel. The United States Department of Agriculture (USDA), Office of Safety and Health Management, tabulated information on lost time accidents due to insects and ticks in the 12 agencies under their direction for 1974 through the first two quarters of 1979. Results showed 92% (1,960 of 2,134) of accidents occurred in the Forest Service. Most were probably due to stinging Hymenoptera, particularly yellowjackets (Akre, 1982).

Yellowjackets are attracted to Christmas tree farms probably because of honeydew produced by aphids. Also, species of *Vespula* and *Dolichovespula* nest in or under the young trees. Information collected in Washington state showed that Christmas tree farming has the highest accident rate of any type of farming. Most accidents are due to shearing knife accidents, while an average 16 percent (1978-1980) are directly attributed to yellowjackets. However, many of the knife injuries also result when personnel are harassed by yellowjackets. A dramatic drop in accidents during the third quarter of 1980 as compared to previous years was attributed to low yellowjacket populations (Akre, 1982).

MONITORING

TIMING AND TREATMENT THRESHOLD

Monitoring is primarily used early in the season to determine the beginning of worker foraging activity. When this is indicated, the population level is closely observed until the treatment threshold level is reached to insure correct timing of abatement measures.

Monitoring can be used to provide the following information: the yellowjacket species composition, the beginning of seasonal (overwintering queen) activity, the beginning of worker foraging activity, the worker activity level, the areas where yellowjacket activity is greatest, indications of yellowjacket outbreaks, and the before/after evaluation of the baiting program in large-scale operations.

Monitoring information must be obtained early in the spring to determine the beginning of queen activity, and usually no later than May to determine the beginning of worker foraging activity. Monitoring information obtained after this time is no longer valuable for timing population reduction measures, which must be implemented soon after worker foraging begins. Population reduction is not feasible during the maximum foraging period, when yellowjacket populations are at their peak.

Because yellowjacket seasonal activity (influencing the timing of monitoring and abatement) may vary slightly by species and also by area, it is important to know the species of yellowjacket and its biology and habits in each area. If necessary, obtain the identification services of a knowledgeable entomologist who can also explain the habits and biology of the species in question (Calif. Dept. of Pub. Health, Env. Mgt. Branch, Public Health Biologists: No. Calif.- Franklin Ennik, (415) 540-2712; Cent. Calif.- Joyce Bradley (916) 739-4056; So. Calif.- Minoo Madon (213) 620-4170).

Activity generally begins later at the higher elevations than in the valleys and coastal areas. For example, near Lake Tahoe, V. pensvlvanica workers begin foraging in the latter half of June, whereas in Marin County, workers may begin foraging a month earlier. The worker foraging period for each species is included in the discussion of Common Species, beginning on page 3.

Once seasonal activity is indicated by any method, the use of observation stations (baited with fish-flavored canned catfood bait or heptyl butyrate attractant) are important to monitor the population level and take action when the treatment threshold level is reached. This involves counting of the number of workers attracted to a bait placement for a period of 10 minutes. This measurement is most accurate at the time of day when yellowjackets are most actively foraging. A toxic baiting program should begin when 10-20 yellowjackets are attracted to bait placement during a 10 minute observation period.

Early-season trapping of new queens has been used to estimate the potential yellowjacket population in an area. One trapped queen is generally representative of 1000-5000 developing workers. Each new queen trapped also results in the elimination of a normally developing colony.

TRAPPING

Trapping for monitoring purposes is not always necessary, particularly if park personnel are routinely working in an area and observing wasp activity. Monitoring traps are more often relied upon in areas which attract yellowjackets but where park personnel activity is less routine. Trapping for monitoring purposes has increased the efficacy of toxic baiting later in the season by increasing the number of yellowjackets attracted to the baited traps. Several methods of trapping for monitoring purposes have been effective. Two of the most popular designs are the cone trap and the liquid trap mentioned below.

Difficulties with the use of attractant in trapping are similar to those experienced with poisoned baits. The only effective chemical attractant available is heptyl butyrate. It is difficult to find, expensive for a large control operation, and will attract only V. pensvlvanica and several other less pestiferous yellowjackets, such as V. atropilosa. Trapping should be timed to minimize the number of individuals of the less pestiferous species that are caught (Ennik, 1989; MacDonald et al., 1973).

Heptyl butyrate seems to be most attractive to yellowjackets when used in dry areas with low humidity.

Cone Trap
Meat baits, such as canned dog food or cat tuna, and chemical attractants, such as heptyl butyrate will trap only the worker caste. There are considerable start-up logistics and costs in early spring to construct the trapping devices. Once the trapping stations are established, the stations must be tended **(1)** at least biweekly to add fresh attractant and **(2)** periodically to empty the dead yellowjackets (Ennik, 1989). See Figure 10 for trap design.

Liquid Trap
The liquid trap is a variation of the cone trap. A number of commercial traps are available in this style, Attractants can be meat baits or synthetic lures. The liquid is usually water with a surfactant, such as oil or dish soap. Once the yellowjackets get caught in the cone or trap, they cannot find their way out and sooner or later fall into the liquid and drown (Ennik, 1989).

ABATEMENT

INTRODUCTION
The most commonly used methods of abatement include: proper management of refuse, trapping with synthetic lures, use of poison baits, and nest destruction (Akre and Davis, 1978). These methods will be discussed in this section.

Because of the beneficial role of yellowjackets in suppressing a wide variety of insect pests, abatement in parklands is the minimizing of human encounters with yellowjackets. The objective is to reduce the number of scavenging yellowjackets in targeted areas, rather than elimination of yellowjacket populations from the parkland. It is often difficult to determine when population levels are high enough to warrant control, since some people tolerate large numbers of yellowjackets whereas others are alarmed at the site of a single worker (Akre et al., 1980). Abatement efforts should target only the areas where yellowjackets are a proven nuisance. Such areas are usually those which attract most human activity, such as around headquarters, picnic areas, visitor centers, concessions, camping areas, and refuse handling areas.

There are two general approaches to abatement: destruction of individual yellowjacket colonies (nest destruction), and area-wide reduction of worker populations. Proper timing is essential for area-wide population reduction. Implementation must begin well before the yellowjacket population reaches a nuisance level, as this level corresponds with the maximum foraging period when colonies have matured and populations are at their peak. Toxic baiting, the preferred method of area-wide population reduction, is effective at an earlier stage in colony development, killing larvae in the nest as they feed on the toxic bait returned to the nest by scavenging workers.

Because timing is so important, monitoring, preventive measures, and population control alternatives should be part of a well prepared action plan for targeted areas to avoid emergencies. In any areas where yellowjacket control is anticipated, yellowjacket abatement should be a priority and become a standard line-item in the annual maintenance budget. Certain abatement activities require considerable start-up time and materials, and managers should be familiar with required resources for each feasible alternative well in advance of the need for implementation.

Contracting with pest control operators should be arranged far enough in advance so that contracting protocol does not delay implementation of early monitoring and preventive measures. If all abatement work is to be accomplished by park personnel, preparations to insure adherence to all current laws and regulations must be taken. The importance of a good public information program cannot be overemphasized.

A strict policy of efficient refuse management must be incorporated into the annual park management maintenance procedures. This must be a permanent high priority in any area where yellowjacket abatement is important.

PREVENTION

The emphasis of yellowjacket abatement should be preventive. Eliminating the food source by proper management of garbage and spilled food denies scavenging yellowjacket workers an attractive and readily available source of protein. When workers are forced to forage mostly for live prey, such as caterpillars, the colony probably does not grow as rapidly since more time is spent to feed each larvae (Akre et al., 1980).

Examples of preventive (sanitation and garbage management) activities:

- Wash food areas where beverages have been spilled
- Sweep food areas in the early morning of each day
- Use snap-on lids for beverages
- Use effective lids on all garbage containers
- Use covered refuse gondolas
- Pick up garbage daily

TRAPPING

Although effective for monitoring population levels, attractant trapping is not an effective control or abatement technique. Traps catch few yellowjackets relative to the amount of time and effort needed for adequate control or abatement (Ennik, 1989). To be effective, trapping requires frequent labor involvement throughout the entire yellowjacket season. Trapping of even enormous numbers of yellowjackets has rarely been effective in alleviating problems caused by wasps scavenging for meat. Even for small areas such as picnic sites, one or two traps placed at a site will not lower the worker population enough to alleviate problems. It may even create an added hazard for site users by exposing them to additional yellowjackets attracted into the area. On a few occasions in late summer, traps have appeared to be successful when yellowjackets were feeding heavily on fruits. At such times, however, the colonies would normally be expected to die within a short time anyway (Koehler, 1990).

If this technique is ever to become an important component of abatement programs, additional highly-specific lures will have to be developed or discovered for all major pest species, and will have to be effective over a wide range of environmental conditions (Akre et al., 1980).

TOXIC BAIT

Toxic baiting is the preferred method of abating yellowjackets. Scavenging workers pick up and carry poisoned baits back to other nest occupants. Baits with encapsulated insecticides will provide better bait acceptance than baits formulated with technical insecticides, which normally repel the insects even at relatively low concentrations. The porus capsule shell masks the chemical odor emitted by the insecticides (Ennik, 1973a).

Microencapsulated diazinon has proven very effective against pest yellowjackets. The only formulation labeled for use against yellowjackets in California is sold by Pennwalt Corporation under the trade name KNOX OUT 2 FM® Insecticide. The preferred abatement measure is a 0.5 percent mixture of microencapsulated diazinon and fish-flavored canned cat food placed in a manner that is accessible to yellowjackets but not to children, pets or animals. Although technical diazinon is highly repellent to yellowjackets and other animals, the encapsulating process greatly masks the strong chemical odor and delays the effect of the insecticide until the workers feed the developing larvae and queen. Many other microencapsulated insecticides have also proved successful in field tests against pest yellowjackets, but the diazinon formulation is the only one with an approved label in California (Ennik, 1989).

Advantages of using toxic baits for yellowjacket control include:

1. Very little pesticide is used (Ennik, 1989).
2. In a well-executed program, only the target animal is affected (Ennik, 1989).
3. Season-long control is achieved with little effort (Ennik, 1989).
4. Their use is specific to the target species (pestiferous scavengers), leaving the beneficial, strictly predacious species undisturbed (Akre et al., 1980).
5. There is minimal contamination of the environment (Akre et al., 1980)
6. The need to locate individual yellowjacket colonies for destruction is eliminated (Akre et al., 1980).
7. It is possible to control yellowjackets early in the season before populations reach a nuisance level (Akre et al., 1980)
8. Colonies can be destroyed before the development of new reproductives late in the season (Akre et al., 1980).

Toxic baiting requires some start-up time and materials. Permanent bait station sites can be established or portable structures can be constructed. To be effective, this program requires daily attention for the first two weeks of control effort. This may conflict at first with other necessary activities but a yellowjacket-free summer is virtually guaranteed (Ennik, 1989)(Appendices 1 and 2).

Timing

Day: Bait stations should be set out as early in the morning as possible. Yellowjackets establish their foraging patterns early in the day (shortly after sunrise) and are reluctant to change them (Ennik, 1989).

Season: One reason to finish the baiting program as early in the season as possible concerns the fate of yellowjackets returning to the nest. Blue jays will eat yellowjackets and can interfere with a baiting program in the latter half of the summer. When jays catch yellowjackets coming out of bait stations, program effectiveness is reduced (by preventing the return of the yellowjacket worker to the nest to feed the poison bait *to* the larvae). In addition, the blue jays may be poisoned. A baiting program which is completed early in the summer will avoid this kind of nuisance and possible secondary poisoning (Ennik, 1989).

It was once believed that the best timing for control was in the spring in order to kill the fertilized queens foraging for food soon after they had emerged from overwintering. This has been shown to be an ineffective strategy. Spradbery (1973) states that "the mass destruction of these potential colony founders seems to have virtually no effect on subsequent wasp populations in the succeeding summer months".

NEST DESTRUCTION

Destruction of colonies within the nest remains one of the principal methods of controlling yellowjackets. The best time for control is after dark when foraging activity has ceased, and the maximum number of workers are in the nest (Akre et al., 1980).

There are a few insecticides commercially available which are labeled for nest treatment. Control would be simpler if yellowjacket nests were easily located as nest destruction is not particularly difficult. However, it is very difficult to track workers back to their nest. Some yellowjackets have been observed flying as far as 3000 feet from their nest in search of food (Arnold, 1966).

Insecticides labeled for nest treatment are usually formulated as dusts or sprays. Although labels on some household aerosol spray products list wasps among the insects they will kill, they are satisfactory only for killing individual wasps. They are not intended for nest use and do not deliver insecticide quickly enough to safely destroy yellowjacket nests (Koehler, 1990).

Although nest destruction is not difficult, there is always the danger of being stung when treating yellowjacket nests. It is suggested that a professional pest control operator be employed for such work if there is a question about personal safety. Protective clothing should be worn which covers the body thoroughly (slick-surfaced materials such as nylon provide better protection than cottons or wools). Rubberized gloves and a hat with a bee veil should be worn; pants legs and jacket cuffs should be tightly secured over shoe tops and gloves. Where possible, nest treatment should be done after dark when the nest is inactive and most of the wasps are inside (Koehler, 1990).

Where it is necessary to destroy an aerial nest, the safest method is to spray the nest with a pressurized bomb, specifically formulated for the purpose, which produces a stream of liquid. 'The nest "should be treated after dark when the nest is inactive and most of the wasps are inside. Several brands of wasp and hornet bombs are available from nurseries and markets, and directions on the product label should be closely followed (Bell and Wagner, 1981).

BIOLOGICAL CONTROL

There is no feasible biological control for yellowjackets at the present time. Parasites, predators, and pathogens have little effect on yellowjacket population dynamics. Biotic agents only have an effect in weakened colonies, levels of parasitism are low, and only small numbers of colonies are affected. Regulation of yellowjacket populations on an annual basis would require that colonies be weakened or destroyed before queen production was initiated (Akre et al., 1980).

A neoplectanid nematode was investigated by Poinar and Ennik (1972) as a possible biological control agent, but the propagation of this parasite requires 100 percent relative humidity. Since this condition is not met in yellowjacket colonies, this agent is of limited use (Poinar and Ennik, 1972; Akre et al., 1980).

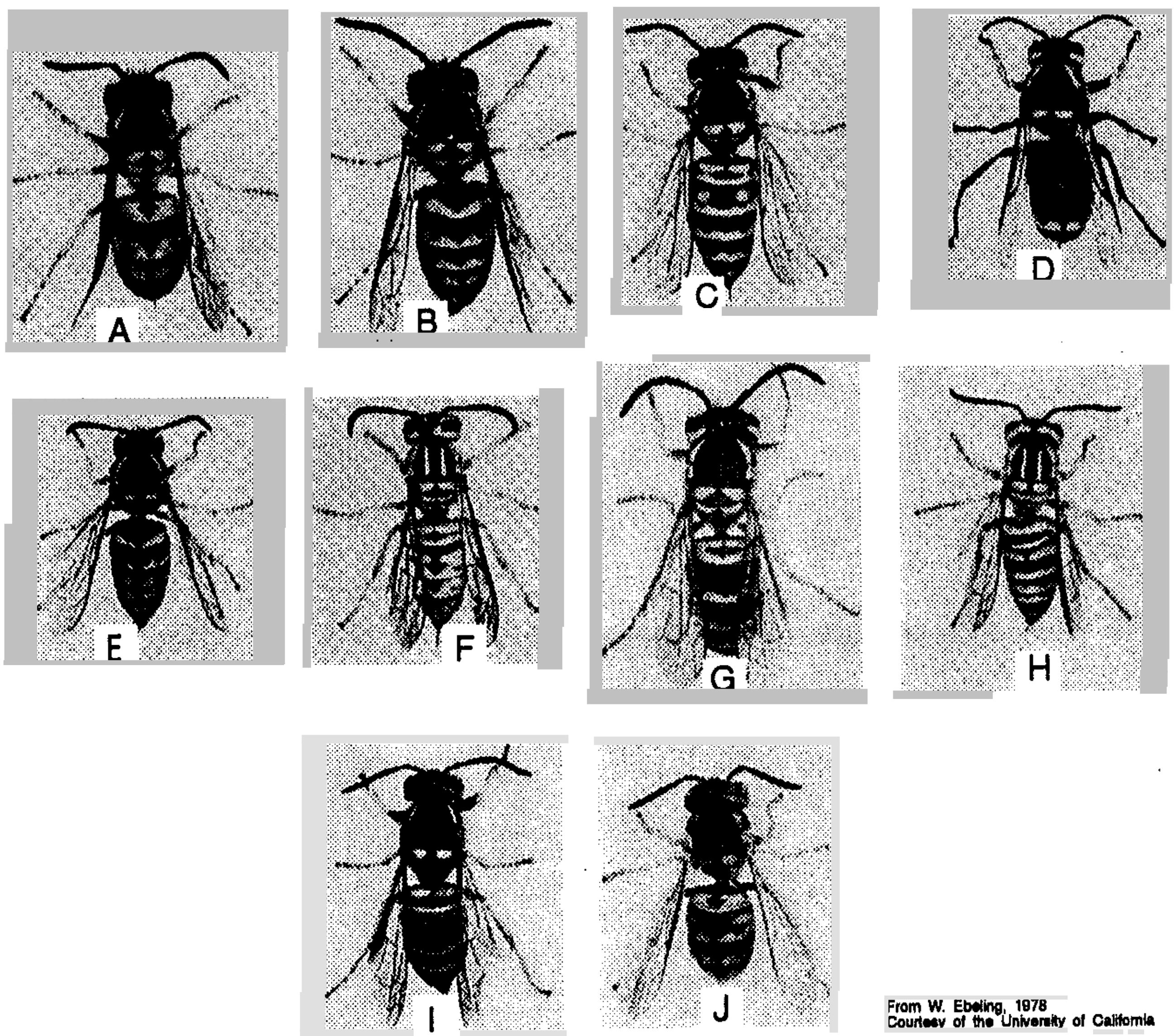
A parasitic phorid fly was recovered from three species of yellowjackets, however it is not considered to be a significant control agent (Ennik, 1973b).

Predators of yellowjacket colonies are few; however, skunks dig up the nests of subterranean yellowjackets and eat the combs. Coyotes, bears and raccoons are known to be occasional predators. Other minor predators include birds, especially robins, which stand near the nest entrance where they catch and eat returning foragers. The impact of these predators on total yellowjacket populations is probably slight (Akre et al., 1980).

Figure 2. The most common western yellowjacket, *Vespula pensylvanica.*

From W. Ebeling, 1978
Courtesy of the University d California

Figure 3. A, *Vespula pensylvanica;* 0, *Vespula vulgaris;* C, *Vespula atropilosa;* D, *Dolichovespula maculata;* E, *Dollchovespula arenaria;* F, *Vespula sulphurea;* G, *Vespula macullfrons;* H, *Vespula squamosa;* I, *Vespula vidua;* J, *Vespula germanica.* (All species have yellow markings on a black background except *Dollchovespula maculata,* which has white markings.)



From W. Ebeling, 1978
Courtesy of the University of California

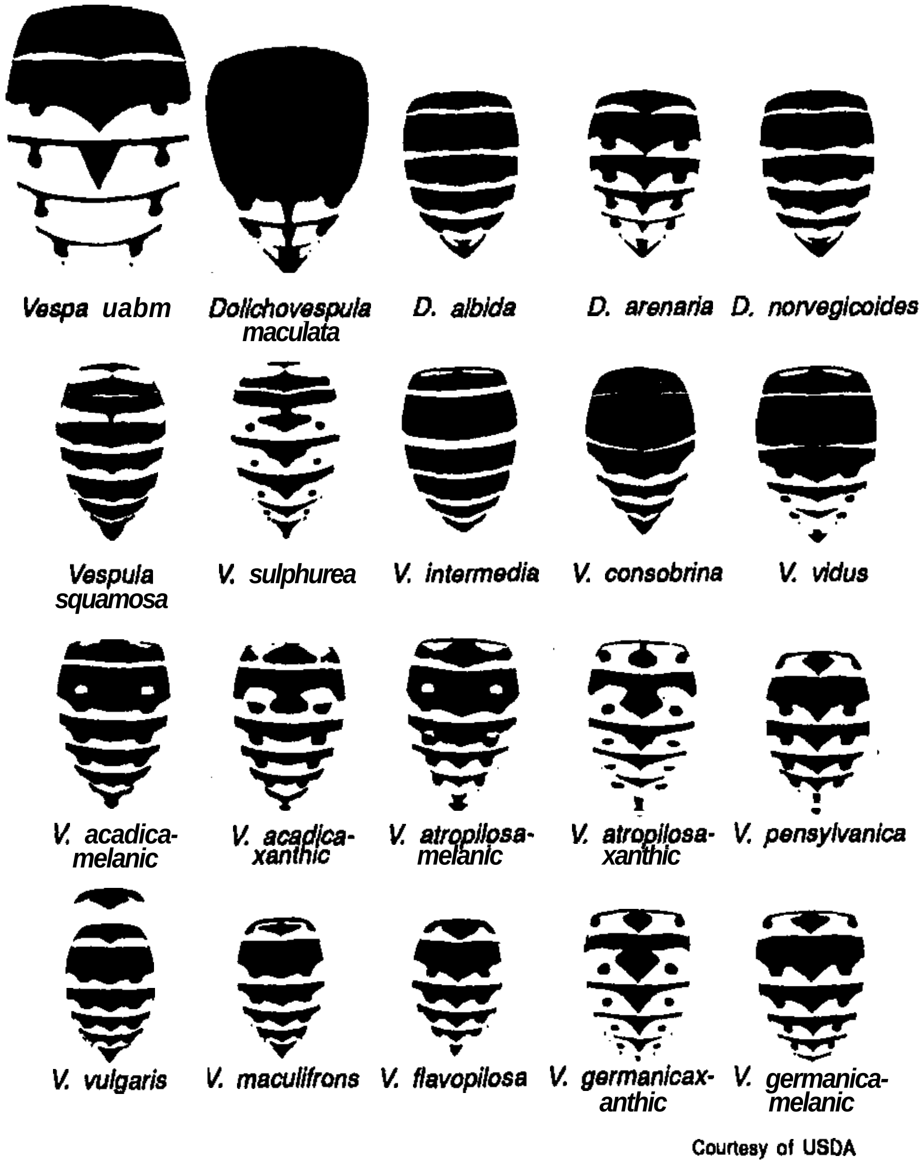
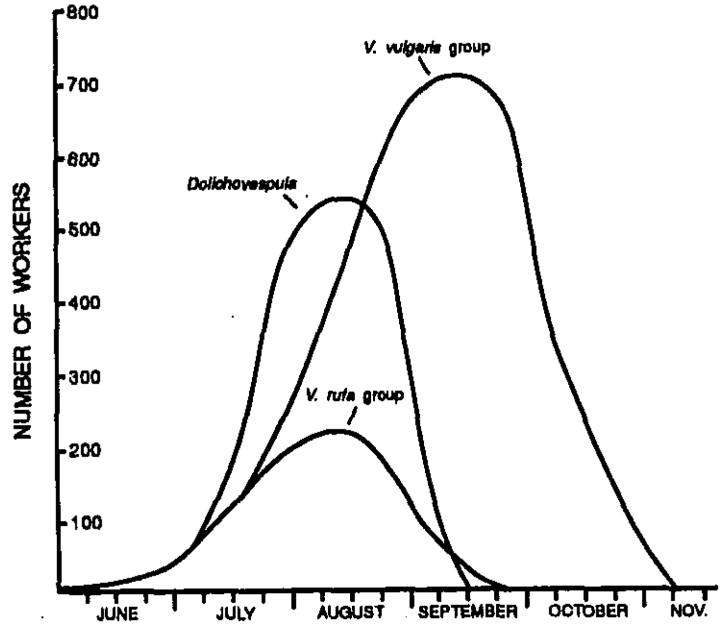


Figure 4. Yellowjacket and hornet worker gaster patterns drawn to scale.

Figure 5. Schematic comparison of colony duration and size of Vespula *vulgaris* species group. *V. rufa* species group, and Dolichovespula ssp. based on number of workers at time of colony collection of *V.* pensylvanica, *V. atropilosa,* and *D. arenaria* in Pullman, Wash.



Courtesy of USDA

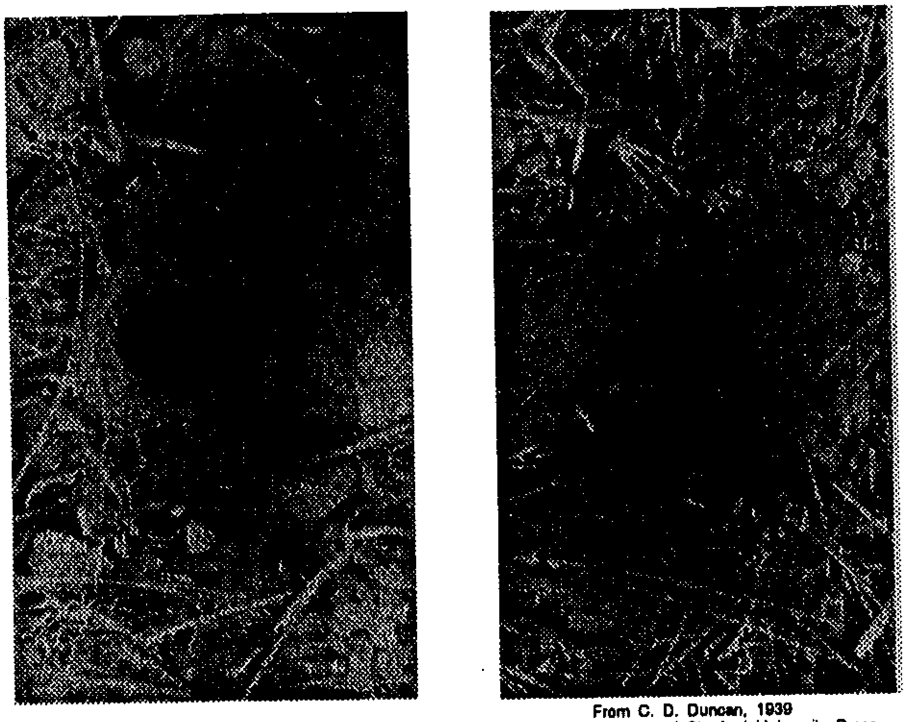
Figure 6. Nest architectural characteristics of genus *Vespula*-subterranean nesting yellowjackets

Species group	Nest architectural parameters
Vespula vulgaris group	**Large nest-ultimately** **3,500 to 15,000 cells.** **Several worker-cell combs.** **All suspensoria cordlike.** Fragile envelope.[1] Scalloped envelope paper.
V. rufa group	Small nest-ultimately 500 to 2,500 cells. One worker-cell comb. Top suspensoria buttresslike. Pliable envelope. Laminar envelope paper.
V. squamosa	Large nest-ultimately 2,500 to 10,000 cells. Several worker-cell combs. All suspensorla cordlike. Pliable envelope. Laminar envelope paper.

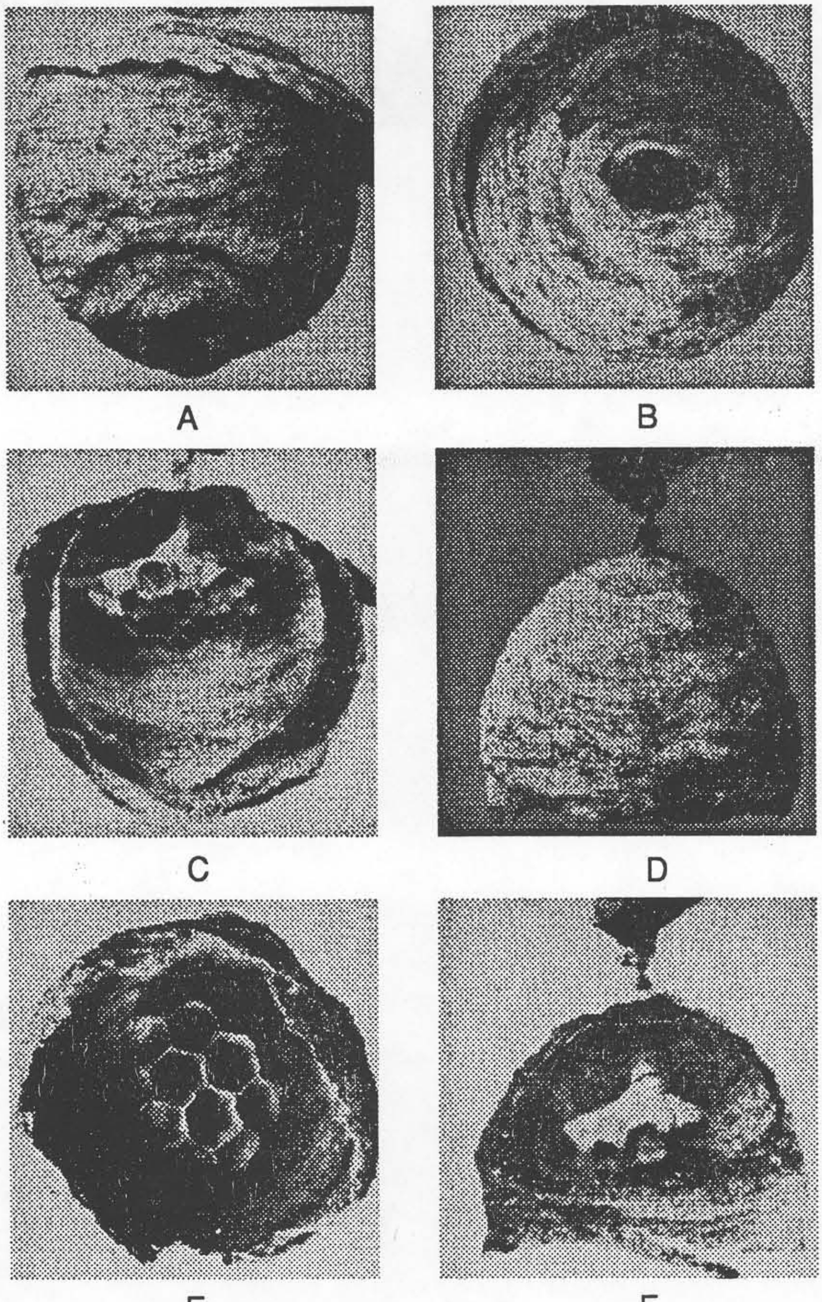
[1]Envelope either gray (*V. pens*ylvanica, *V.* germanica) or tan (*V. vulgaris, V. flavopilosa, V. maculifrons).*

Courtesy of USDA

Figure 7. Ground nest entrance.



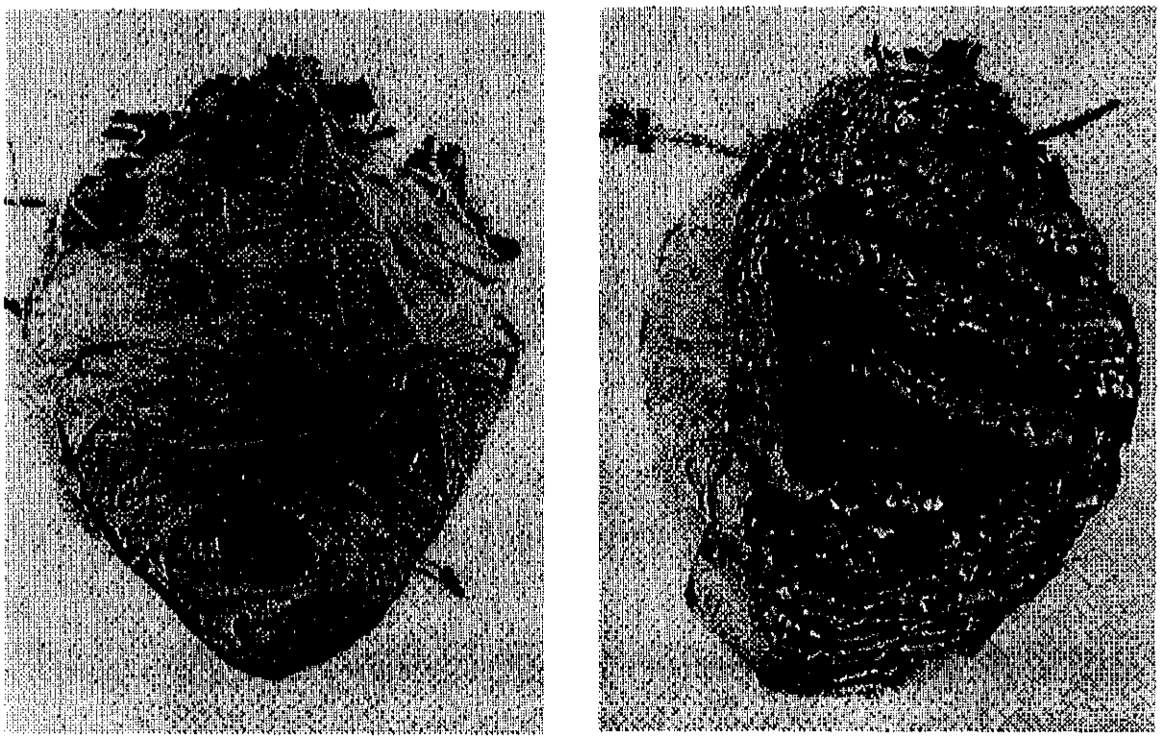
From C. D. Duncan, 1939
Courtesy of Stanford University Press



From C. D. Duncan, 1939
Courtesy of Stanford University Press

Figure 8. A - Side view of queen nest of *Vespula pensylvanica* (Sauss.), built in dark shed near Hoberg's Lake County, California
B - Ventral view
C - Longitudinal section
D - Side view of queen nest of *Vespula pensylvanica* (Sauss.), from rodent burrow, four inches below the ground surface on hillside near Middletown, Lake County, California
E - Ventral view
F - Longitudinal section

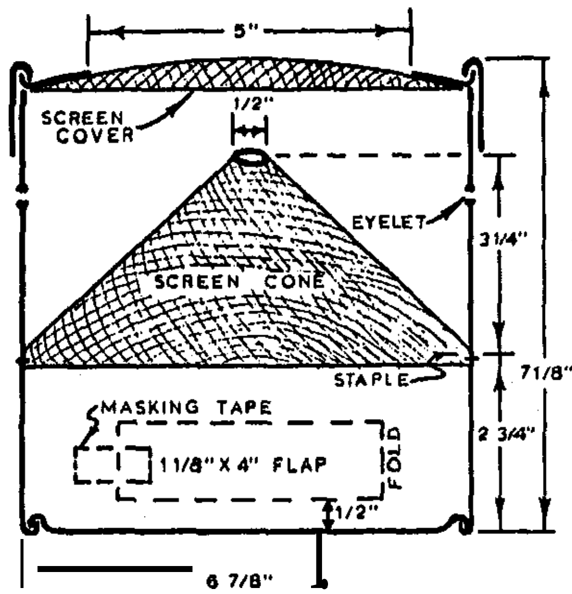
Figure 9. A - Mature nest of *Dolichovespula arenaria* (Fabr.), built in a poison oak bush three feet from the ground. B - Same nest with half of early envelopes left above the combs.



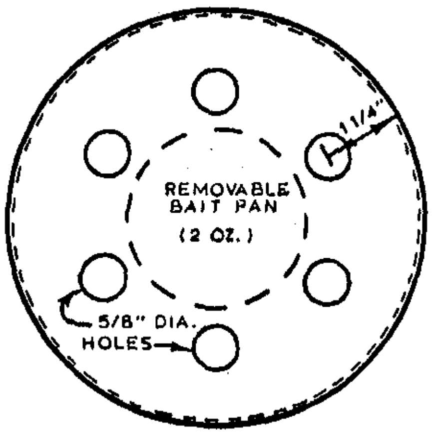
A B

From C. D. Duncan, 1939.
Courtesy of Stanford University Press

Figure 10.



CONSTRUCTION DETAIL



BOTTOM DETAIL

A STANDARD YELLOWJACKET TRAP FOR POPULATION SAMPLING AND CONTROL EVALUATION

The necessity for standardization in population evaluation methods Is a primary need in any continuous program of yellowjacket (Vespidae) control. The primary sampling tool is an evaluative trap designed to meet several basic criteria: (a) low-cost production; (b) relatively efficient yellowjacket trapping, (c) provisions for easy baiting and yellowjacket removal; (d) protection of bait from various birds, mammals, and invertebrates; (e) derate durability to weather and handling conditions; (f) minimal size for transportation and storage; and (g) freedom from repellent factors of odor, color, and composition.

With construction and testing of many trap models, study was made of yellowjacket habits and sensory functions entailed in entry and escape from baited traps. Some specially designed traps were highly efficient but deemed impractical for bulk use in an extensive evaluative program. The standard evaluative trap finally selected In a modified fly trap, Initially used by the Bureau of Vector Control, (Calif. Dept. of Pub. Health) which Is easily made from a 1 gallon ice cream carton.

Thin simple closed cylinder has peripheral entry orifices on the bottom surface surrounding a centrally placed bait pan with a screened top lid serving as a false escape way above a 45 degree screen cone within a closed cylinder. Trap effectiveness is based on the strong tendencies of these yellowjackets to seek entrance at the bottom of such containers and escape in an upward-direction. especially toward in overhead light source. After orientation circling on rising from the attractant bait pan, the yellojackets readily land on the screening at the cone apex and crawl upward through the 1/2 inch orifice. The trapped yellowjackets above the cone die fairly rapidly and fall to the periphery of the cone base so that large collections significantly reduce the area of overhead light reaching the bait area. However, trap capacity has demonstrated continued effectiveness with as many as 4000 trapped yellowjackets over a 3-day period.

TRAP CONSTRUCTION--The trap was constructed from a Sealright®, plastic-treated. rolled-cardboard, I-gallon ice cream carton. For construction of the trap, the lid was taken off the carton and the bottom was removed by unfolding the crimped lower edge and pushing It out.

The carton bottom was punched with six 5/8 inch diameter holes equally spaced 1 1/4 Inch on center from the circumfersnce. A punch for this purpose was made by sharpening one end of a short piece of 1/2 inch Inside diameter water pipe. To make the holes, the carton bottom was placed on a soft block of wood and the punch was struck by a sharp blow with a hammer.

The cone waa prepared from 16-mesh aluminum fly screen (standard window screening) by cutting an 11 1/4 inch diameter circle with a 100 degree wedge removed. The cone was formed by closing the wedge, overlapping the edges approximately 1/2 inch, and stapling them together. The apex of the cone was trimmed to leave a 1/2 Inch diameter *hole.* The cone was then inserted into the carton and stapled in place with the bottom edge of the cone 2 1/2 inches above the bottom edge of the carton. A stapler with an 8 inch throat was used.

A 1 1/8x4 inch flap-type door, for inserting and removing bait, was made in the side of the carton by cutting along the top, bottom, and one end of the door area; the bottom of the door was 1/2 Inch above the bottom of the carton. The door was folded out along the uncut end to form a hinge. Masking tape was used to hold the door closed.

A centered 5 inch diameter hole was cut in the carton lid. A 7 inch diameter circle of 16-mesh aluminum fly screen was cut and Wedged into the lid from the under side, producing a convex screen cover which remained in place with no additional fasteners. When the lid was replaced on the carton, the screen was held securely in place by the upper edge of the carton.

Two eyelets Were placed on opposite sides of the carton slightly below the lower edge of the lid (when in place) to accept wires for trap suspension.

Reassembly of the modified carton parts completed trap construction.

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APPENDIX 1

SUGGESTED OUTLINE FOR YELLOWJACKET ABATEMENT (UTILIZING KNOX OUT 2 FM® IN A CAT FOOD BAIT)

1. DETERMINE THE SPECIES OF YELLOWJACKET. Most yellowjacket species are not pests and some do not respond at all to baiting programs. If necessary, obtain the identification services of a knowledgeable entomologist who can also explain the habits and biology of the species in question.

2. DETERMINE POPULATION LEVELS BY OBSERVING NUMBERS OF PEST YELLOWJACKETS ATTRACTED TO TUNA CAT FOOD BAITS OR TO THE CHEMICAL ATTRACTANT, HEPTYL BUTYRATE (OPTIONAL). Start monitoring population levels early. When numbers of foragers reach sufficient levels (10-20 wasps/ 10 minutes), start the baiting program.

Note:
* Not all yellowjacket species are meat-eaters nor will all respond to chemical lures such as heptyl butyrate.
* Monitor traps are optional (for design, see Grant et al., 1968. J. Econ. Ent., 61(6):1653, and Rogers et al., J. Econ. Ent., 61(6):1739). These devices provide an indication of the before/after success of the baiting program in large-scale operations.

3. MIXTURES SHOULD CONTAIN NO MORE THAN 1/2 TEASPOON OF KNOX OUT 2 FM® PER 6 OUNCES OF BAIT (APPROX. 0.5% FORMULATION). Using more is unnecessary and will make the mixture increasingly more repellent. The higher toxicity allows fewer round trips by the foraging yellowjackets between the bait station and nest.

For best results, bait dispensers must be tended regularly and bait portions replaced at least twice weekly (for example Monday and Thursday) for the first two weeks. Ideally, bait portions should not exceed what can be removed by the yellowjackets in two days.

Bait portions should be prepared fresh, despite claims by others that premixed, frozen preparations work just as well. Use no additives other than water and/or vegetable oil (for moistening agent). Other additives enjoy equivocal or unfavorable results. Mix thoroughly.

4. BAIT DISPENSERS SHOULD BE PLACED PREFERABLY IN SHADE OR UNDER TREES (BUT NOT IN TREES), ABOUT 2 METERS ABOVE GROUND, AROUND THE PERIPHERY OF THE AREA TO BE PROTECTED. Some means of protecting wildlife and children must be engineered into constructing and placing the bait dispensers. Bait dispensers must be properly labeled that they contain pesticide, and ideally have a "Mr. Yuk" symbol attached. Exposing the bait dispenser directly to the sun will cause the bait to dry out and quickly become unattractive to the yellowjackets.

It is important to place the bait dispenser in the morning as early as possible. Yellowjackets establish their foraging patterns early in the day and are reluctant to change them.

The feeding activity of the pest yellowjackets will be severely reduced after 2-4 bait exposures (in some cases after the first exposure). A second round is usually necessary but is not needed until 10-14 days later if a drastic reduction of foraging wasps is noticed (See Ennik, 1973b).

5. The bait dispensers illustrated in brochures or provided by Pennwalt Corporation in kits are satisfactory but the entry holes are too small. Round entry holes will not permit a yellowjacket with a load of bait to easily exit the bait dispenser. Constructed enclosures should be made with 3/4 inch hardware cloth or equivalent.

From Ennik, 1984

SUGGESTED MATERIALS NEEDED

Tuna cat food: 9-Lives® brand cat food tuna, 6 ounce. Available at many grocery stores.

Bait pan: Small aluminum pans, half pint containers, styrofoam® containers, or equivalent. Do not use tin cans because the metal imparts repellent effect.

Encapsulated Diazinon: KNOX OUT 2 FM® labeled for yellowjacket control. Insecticide available from:

Target Chemical
1280 - No. 10th Street
San Jose, CA 95112
(408) 293-6032

VWR-Agri-Division
San Jose, CA 95131
(408) 435-8700

The smallest quantity available is quart size, approximate cost $50.00.
NOTE: One pint of insecticide may be enough for 2 or 3 seasons of baiting. The shelf-life of this formulation is very stable, provided it does not evaporate out. It is a water suspension and must be shaken well before use. The company claims, however, that the shelf-life of some batches has been variable.

Optional: Heptyl butyrate, available from various chemical supply companies. Buy small quantity--half pint.

Additional useful items: Hole punch for paper; test tube brush for heptyl butyrate; finishing nails; mixing container and stirrer; can opener; hammer; pliers; measuring spoons; wire screen/hardware cloth

From Ennik, 1989

APPENDIX 2

SUGGESTIONS FOR KNOX OUT 2 FM® YELLOWJACKET BAIT STATION PROGRAM

1. Have label (including supplemental label) with you whenever baiting stations.
2. Place all stations out of reach of both children and pets.
3. Place stations in areas that are not visited by either people or pets.
4. Service bait stations frequently.
5. Pre-bait with meat alone to determine if the trap is properly located.
6. Start insecticide baiting program with small amounts. Increase the amount as demand increases.
7. Place stations in sunny locations.
8. Bait either early in the morning or after the sun goes down, unless you are wearing protective clothing.
9. Eliminate competing food and water sources.

From Bissell, 1990

APPENDIX 3

CONTROL SUMMARY

1. Yellowjackets, including scavenger species should not be controlled or eliminated unless they are pestiferous because all yellowjackets are beneficial.
2. All colonies should be exterminated at night when the workers are least active and the maximum number are within the nest.
3. Subterranean colonies can be eliminated with the use of insecticides such as carbaryl or propoxur. These insecticides are poured into the entrance tunnel which is then plugged with cotton. The plug and surrounding soil should also be treated to kill any foragers returning the next day. Certain aerosols will also effectively control colonies if the nest is near the entrance hole.
4. Colonies in wall voids are effectively controlled by use of a synthetic pyrethroid generator and application of carbaryl dust to the plugged entrance hole.
5. Aerial nests can be easily treated with aerosol products containing a quick knockdown insecticide. Several types of commercial products will propel a thin stream of insecticide and solvent up to 3 meters or more. Aerial nests may also be sprayed with conventional insecticides such as propoxur.
6. Simple traps using fish as bait with a pan beneath containing water and a wetting agent can be quite effective in lowering populations of yellowjackets in small areas. These traps have the advantage of being specific for scavenging species. Other traps using fish as bait and a reverse cone to trap entering workers are effective but not as convenient as other methods.
7. At the present time, poison bait formulations are effective only against V. pensylvanica and, to a lesser extent, against V. vulgaris. The only effective programs utilizing this technique were in California. More research is needed to discover acceptable baits for pestiferous species in other areas.
8. Synthetic lure traps containing heptyl butyrate or other attractants have been used effectively to abate populations of V. pensylvanica in some arid areas of Washington and Oregon. In most areas of North America, these lures have no value as most species are not attracted. Hopefully, future research will uncover additional compounds that are differentially attractive to some of the other species. This type of trapping is not recommended for homeowners.
9. One of the best methods of reducing contact with yellowjackets (and perhaps even reducing populations) in urban areas is to control garbage by making it less available to scavenging workers. Treatment of trash containers routinely with dichlorvos sprays or placing an insecticide impregnated strip in the garbage can lid also helps.

From USDA Agriculture Handbook 552